Technical white paper

Calibration Best Practices for the HP DreamColor Z27x Professional Display

Z7X230/Z7X240 Firmware Release, September 2014

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Document Version Information

This document includes StudioCal XML commands that are new in the Z7X230 and Z7X240 firmware revisions. If you are running an earlier firmware version and using StudioCal XML please upgrade to the latest version and check your XML code against the information in the Calibration Customization with StudioCal XML section on page 6. (Note: the Z7X230 and Z7X240 firmware revisions are functionally identical. The only change is the added support for a new SoC memory configuration in the factory.)

Introduction

The HP DreamColor Z27x Professional Display has a built-in calibration engine which allows for very accurate display calibration using a number of different measurement instruments and enables multiple calibration strategies. This document will discuss calibration in detail and will provide information on measurement instrument configuration and calibration methodology.

Supported Measurement Instruments

The Z27x provides native support for many different types of measurement instruments, from a low-cost colorimeter to high end colorimeters and spectroradiometers. They were chosen because HP's studio partners had standardized on these instruments. Some of these instruments require specific configurations or calibrations in order to work properly with the Z27x.

All of these instruments use USB to connect to one of the two HP DreamColor USB ports on the Z27x display. No host-based software is required for their operation but may be required for instrument configuration and calibration.

Important
With all of these instruments it is very important that the measurement instrument is positioned perpendicularly to the face of the display.

The following section describes each instrument and how it works with the Z27x.

Klein Instruments

The Z27x supports the direct connection of the Klein K10-A colorimeter. This is a high-speed, very accurate lightweight device that supports direct monitor contact or can alternatively be used in a darkened room as a distance unit. As the instrument is designed to only be used via a USB connection, there is no display on the instrument and it cannot be used for independent measurement.

Configuration
New Klein K10-A instruments come from the factory pre-calibrated with a Z27x matrix stored as cal file 14. If you have an existing unit it is strongly recommended that you send your instrument to Klein for recalibration. However, if you are comfortable with building a calibration matrix and have access to a spectroradiometer you can use the ChromaSurf program to generate your own calibration matrix. It is recommended that you store your custom matrix as cal file 14 as that is the one loaded by default when the K10-A is connected to the display. However, it is possible, via StudioCal.XML, to specify any cal file for use in calibration, allowing you to store a custom matrix in the location of your choosing. We will discuss this option later in this document.

Usage Guidelines
The following guidelines are recommended when using the Klein K10-A with the Z27x:

- The Z27x may take up to ten seconds after instrument connection to display the first calibration menu. This is normal for this instrument as it is USB-powered and must boot up before it can respond.
- Direct contact measurement is recommended using the K-10 SF Lens Hood. This allows you to calibrate the display under typical room lighting (though dimmed lighting is still recommended for best black measurements).

  If using distance measurement it is strongly recommended that you use a completely darkened environment for calibration.
- Check and, if necessary, use ChromaSurf to recalibrate the black level prior to calibration. The K10-A should hold its black level calibration for an extended period, but if recalibration is necessary it is a very quick procedure.

If, after display calibration, the Z27x shows the lower grayscale as light gray with little to no shadow definition then you need to recalibrate the K10-A's black level and then recalibrate the display.

Photo Research

Photo Research is a highly-respected manufacturer of measurement instruments and the Z27x supports the majority of their spectroradiometers. The following instruments are supported:

- PR-655 SpectraScan
- PR-670 SpectraScan
- PR-680 / PR-680L SpectraDuo
- PR-730 SpectraScan
- PR-740 SpectraScan

The Photo Research instrument must have the USB interface. This is optional on some models but is required for connection to the Z27x display. If multiple interfaces are supported by the instrument the USB communication method must be enabled and active.

Configuration
These instruments contain a wide number of configuration options, all of which can be set via the touchscreen LCD interface on the back of the instrument. The following table lists the recommended configuration for each display.

Table 1. Recommended Settings for Photo Research Instruments

	PR-655	PR-670	PR-680	PR-680L	PR-730	PR-740
Minimum Firmware Version	3.12	3.14	3.14	3.14	3.10	3.14-74X
Bandwidth	8 nm	—	—	—	2 nm	2 nm
Aperture	—	1 deg	1 deg	1 deg	1 deg	0.5 deg
Adaptive	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
Sensitivity	—	Extended	Extended	Extended	Extended	Extended
Speed	—	Normal	Normal	Normal	Normal	Normal
Sync	Auto	Auto	Auto	Auto	Auto	Auto
Smart Black	—	Disabled	Disabled	Disabled	Disabled	Disabled
Sensor Mode	—	—	—	Spectro	—	—

Usage Guidelines
The following guidelines are recommended when using a Photo Research spectroradiometer with the Z27x:

- The Z27x may take up to five seconds after instrument connection to display the first calibration menu. This is normal for this instrument.
- As this instrument is typically used for non-contact measurements, and typically at a distance of one or more feet, it is critically important that all measurements be made in a completely darkened environment.
- Contact measurements can be made using one of the flexible probe options, but care must be taken to properly mount the probe so that it is perpendicular to the display surface.
- For best results, be sure to follow the recommended instrument recalibration schedule.

Konica Minolta

The Konica Minolta CA-310 is high-speed colorimeter that is very popular, especially in Asia. Designed for both independent measurement and to be driven externally, the instrument comes in two parts, the main body, containing the core logic hardware, and a lightweight measurement probe. The instrument should be connected to the monitor via a USB A to USB B cable.

Configuration
The instrument must be set to xyLv measurement mode. Most critically, as this device is a colorimeter, a user calibration (both white point and matrix) *must* be done prior to any display measurements being made. The user calibration can be stored in any memory channel, but that channel must be selected prior to connecting the instrument to the display.

Usage Guidelines
The following guidelines are recommended when using the Konica Minolta CA-310 with the Z27x:

- The Z27x may take up to ten seconds after instrument connection to display the first calibration menu. This is normal for this instrument.
- Black level (zero) calibration must be performed each time after the instrument is powered on. If calibrating multiple displays, Konica Minolta recommends that zero calibration be performed every hour, especially if calibrating to a low luminance target, such as 48 cd/m^2.
- Confirm that the instrument has been properly calibrated and the memory channel you calibrated is active.
- Direct contact measurement is recommended using the standard hood. This allows you to calibrate the display under typical room lighting (though dimmed lighting is still recommended for best black measurements).

  If using non-contact measurement the instrument distance can be no more than 30 mm from the display surface. It is also strongly recommended that you use a completely darkened environment for non-contact measurement.

HP DreamColor Calibration Solution

HP also offers a low-cost calibration solution, the HP DreamColor Calibration Solution (DCS). The DCS kit includes both an HP-branded X-Rite i1Display colorimeter and a calibration software CD which is designed to be used on other HP displays including the DreamColor LP2480zx and DreamColor Z24x. This software does not need to be installed on a computer in order to calibrate the Z27x display as the i1Display instrument is directly-connected to the Z27x. Indeed, if the software is installed, it will not recognize the display. Retail versions of the i1Display are not currently supported with the Z27x.

Configuration
There is no configuration required for the DCS i1Display instrument. If purchased prior to the release of the Z27x, the display will automatically install the correct calibration matrix into the instrument when it is connected.

Usage Guidelines
The following guidelines are recommended when using the DreamColor Calibration Solution i1Display with the Z27x:

- The Z27x may take up to five seconds after instrument connection to display the first calibration menu. This is normal for this instrument.
- This instrument should be used in direct connection mode with the counterweight adjusted to maintain the instrument position during calibration. If using this instrument on a Z27x with an attached hood, use the hood door to mount the instrument.
- Even though the instrument does a good job of blocking ambient light it is still recommended that calibration be conducted in a dimly lit environment.
- The ambient light filter must be rotated away from the instrument lens prior to measurements being made. If left in place measurement errors will occur.
- The DCS i1Display has an error tolerance for factory calibration of each instrument. Visible calibration differences can occur if a different probe is used for each display. We strongly recommend that a single DCS kit be used to calibrate all displays within a facility or workflow.

Calibration in Practice

The Z27x has a built-in calibration engine and does not require a computer host to calibrate. User calibration can be performed in two ways:

- On-screen menu-driven calibration or recalibration

  This option provides basic calibration choices and is suitable for single-user calibration when standard color space primaries and gammas are desired. It can also be used to perform a recalibration of any color space preset, even those that are originally calibrated using the StudioCal.XML option described below.

  On-screen calibration also includes the ability to perform a calibration validation pass. Connect an USB memory device to the second DreamColor USB port prior to calibration. Once the calibration is finished a series of test patterns including primaries, secondaries, and the X-Rite ColorChecker patterns will be displayed and measured. The results are written to a text file on the flash drive and given a filename that includes the serial number of the display calibrated. This text file contains all of the target values and measured results for both the calibration and validation passes. The data is recorded in CIE XYZ format.

- XML-driven calibration using StudioCal XML

  This option provides the greatest calibration flexibility as it allows you to do much more than a standard calibration. Options include:
  - Specification of custom color space primaries
  - Performing a customized validation pass post-calibration
  - Archiving of calibrated LUTs to the USB flash drive
  - Overwriting the factory calibration memory store
  - Direct upload and download of color space preset LUTs (without a calibration pass)
  - Contrast ratio limiting

  These options will be discussed later in this paper.

This technical white paper focuses on the StudioCal XML calibration approach. Refer to the Z27x User Guide for more information on the menu-driven calibration option.

Preparing for Display Calibration

Though a display can be calibrated at an artist's or user's desk, if multiple displays are to be calibrated, a good strategy is to identify a light-controlled area where you can perform the calibrations. This area should allow for multiple displays to be staged and warmed up prior to calibration. If using an instrument on a fixed tripod, as is common for the Photo Research instruments, we recommend that you line up one display so that it is properly positioned relative to the instrument and then mark the table/bench position of the display or use a mounting jig. Doing so will allow you to quickly position each display at the proper measurement location.

Calibration Environment

The recommended calibration environment will vary depending on the instrument you are using for calibration. If you are using a direct-contact instrument, such as the Klein K10-A or the DreamColor Calibration Solution, we recommend that you calibrate in dim lighting with no direct lighting hitting the screen. If you are calibrating using a non-contact instrument we strongly recommend that you calibrate in a completely darkened room or that you use a dark enclosed environment, such as a calibration box, for calibration.

Display Warm-Up

The LEDs used in the Z27x backlight require a period of stabilization before the display is calibrated, we recommend that the displays be allowed to warm up so that the backlight can stabilize. The display's internal timer is configured to warn you if you attempt to calibrate within 30 minutes of the display being turned on. However, our internal testing of the backlight stability indicates that if the monitor is kept at standard room temperature the backlight is stable within seven minutes. This number was derived from timed measurements using a Photo Research PR-740 spectroradiometer.

Warm-Up Mode

To facilitate a bulk calibration workflow where multiple monitors will be calibrated or recalibrated in a single session, the display includes a standalone warm-up mode. This mode allows you to warm up multiple monitors without connecting any of them to a host computer.

To enable the standalone warm-up mode:

1. Connect the display to a power source and ensure that the hard power switch at the bottom of the display is turned on.

   Depending on the display's configuration, it may immediately power on once the hard power switch is activated.

2. Power the display on, if necessary, and then off again using the *soft power* button on the lower right of the bezel.

   This first power up boots the internal hardware while the power off again puts the hardware to sleep.

3. Using the buttons on the lower right bezel, hold the top bezel button down then press and release the bottom bezel button. After the bezel lights illuminate you can release the top bezel button.

The display will now enter warm-up mode and the display will begin to cycle between full-screen white, red, green, blue, cyan, magenta and yellow. If an active source device is connected to any of the display's inputs, burn-in mode will turn off and be replaced by the source's output. If the source is disconnected, though, warm-up mode will resume when the source is no longer present.

Note: To disable warm-up mode, turn the display on and off via the bezel power button.

Calibration Frequency Recommendations

HP has been performing real-time continuous ageing on a set of Z27x displays since November 2013. As of the release of the Z7X230/Z7X240 revision of this document we have accumulated over 7500 hours of real-time ageing data for this display. Based on current ageing data we make the following recommendations to maintain display accuracy:

- As with all LED backlit displays, there is a burn-in period where the LEDs will drift slightly until they "settle down." Though the amount of burn-in drift will vary from display to display, we have observed a typical white point drift of approximately 1.0 Delta E 2000 after 250 hours.

  Therefore, we recommend that you recalibrate the displays after 250 hours. (If you wish to pre-burn-in displays prior to calibration and deployment, 250 hours is equivalent to approximately 10 ½ days of continuous burn in.

- One you have passed the burn-in period, the display's chromaticity is extremely consistent. We have observed stability (to within 1.0 Delta E 2000) for over 2500 hours between calibrations. We have seen this to be consistent over the ageing data we have accumulated, but it is always best to be somewhat conservative with calibration frequency.

- Therefore, we recommend that you calibrate your Z27x displays every 2000 hours. (As many facilities wish to be conservative in their calibration frequency, you may choose to calibrate more frequently.)

We will continue to perform real-time continuous ageing and will update these recommendations as needed.

Calibration Customization with StudioCal XML

StudioCal is a custom-designed XML schema that provides the ability to customize the Z27x calibration. It contains tags that allow you to specify the calibration targets, adjust the calibration to add linear segments or contrast ratio limits, download and upload LUTs to/from the display, and even backup and restore the display's complete configuration.

New Commands in this Revision (Z7X230/Z7X240 Firmware Release)

HP has designed the StudioCal XML schema to be extendable so that additional capabilities can be added. New capabilities have been introduced with each firmware revision. This document will be revised with each firmware update. When firmware is updated please download the updated version of this document to check to see if there are changes to existing tags.

The Z7X firmware revision adds support for BT.1886 gamma calibration, custom Klein cal files, and enhancements to the upload/download LUTs procedure. Please check the relevant sections below to learn more about these changes.

File Name and Disk Format

When a USB drive is inserted into one of the two DreamColor USB ports, the display looks for a file named `studiocal.xml`. This file will then be opened, parsed, and used for calibration. The display will not look for any other XML files, so the naming must be exact.

USB drives containing a studiocal.XML file may be formatted using FAT16, FAT32, or NTFS.

Structure

As XML, the standard XML declaration statement must be on the first line of the file. It should be structured as follows:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
```

All StudioCal commands must be enclosed in a `<studiocal>` root element. The final command in the XML file must be a closing tag for the root element (`</studiocal`).

Comments

XML comments are supported and are useful to indicate the procedures performed by the XML file. For example, a StudioCal XML file that calibrates the BT.709 color space preset might include the following comment line:

```
<!--BT.709 calibration-->
```

Core Calibration Tags

There are three core calibration tags. These must be present in any StudioCal XML file that is to be used for calibration with an attached instrument. However, if the StudioCal XML file is not being used for calibration – if it is being used only to upload a set of LUTs, for example – these commands should not be included. The three core calibration tags are:

Preset

This tag is used to specify the color space preset number, preset name, and the type of memory store used to hold the calibration data. The tag and attributes are structured as follows:

```
<preset num="INTEGER" name="ALPHA" store="user|factory"/>
```

- **num**: Specifies the preset memory location. The Z27x has seven preset memory locations, numbered 0 through 6. These presets are presented in the on-screen menus in numerical order from top to bottom. The following table lists the default color space presets and their preset number.

Preset Name	Number
sRGB D65	0
sRGB D50	1
AdobeRGB	2
BT.709	3
BT.2020	4
DCI P3	5
Native	6

Only preset numbers 0 through 6 are supported. Any other number will generate a syntax error. It is *strongly* recommended that the Native preset (preset num 6) be left as native. It is extremely useful to have a preset available that will display the native primaries of the display's LCD panel. For example, proper use of the external_primaries tag requires that native measurements be made. If you have replaced the Native preset with another calibration you will not be able to make these measurements.

- **name**: Specifies the name that is assigned to the preset. This name will appear in the onscreen menus. Names can be up to fifteen characters in length and may consist of alphanumic (A–Za–z0–9) characters, a period (.) and a space. All other ASCII characters are converted to periods.

- **store**: Specifies the memory store that will be used and accepts the values "user" or "factory". The Z27x contains two different memory stores: factory and user.
  - The factory store is a protected memory location where the factory calibration is stored. When a calibration is written to the factory memory location, the user memory location is also rewritten to match the factory memory location. This location can only be rewritten via StudioCal.XML and this option is provided to allow facilities and studios to store a calibration that can easily be recalled via the "Reset to Factory Calibration" or "Factory Reset" command.

– The user store is the memory location where all menu-driven calibrations are stored. This memory location is not protected and will be rewritten when any type of calibration is performed or if a "Factory Calibration" or "Factory Reset" command is issued.

Important

Overwriting the factory memory location means that you can no longer restore to the display's original calibration. While this is desired in most cases, you will not be able to restore the original calibration if you have a measurement instrument problem. It is recommended that you confirm that the instrument is properly functioning before using the factory memory location.

Target_primaries

This is the primary calibration tag. It allows you to specify, using CIE xy or CIE u'v', the target color primaries (red, green, blue) and white point, plus the luminance in cd/m^2. Two additional attributes are also supported, as noted below. Unless otherwise noted all attributes are required. The tag and attributes are structured as follows:

```
<target_primaries rx="FLOAT" ry="FLOAT" gx="FLOAT" gy="FLOAT" bx="FLOAT"
by="FLOAT" wx="FLOAT" wy="FLOAT" wY="INTEGER" use_uv="xy|uv"
external="TRUE|FALSE"/>
```

- **rx**: The CIE x or u' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **ry**: The CIE y or v' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **gx**: The CIE x or u' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **gy**: The CIE y or v' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **bx**: The CIE x or u' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **by**: The CIE y or v' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **wx**: The CIE x or u' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **wy**: The CIE y or v' value for the red primary. Supports floating point values from 0.0 to 1.0. Values that position the color primary outside of the CIE locus will generate a calibration error.
- **wY**: The target luminance, specified in candelas per square meter (cd/m^2). Values from 48–250 cd/m^2 are supported.
- **use_uv**: (optional) Specifies whether CIE xy or CIE u'v' values are provided for the primaries and white point. This attribute accepts the values "xy" or "uv". If this optional attribute is omitted from the tag xy values are assumed.
- **external**: This attribute is used in conjunction with the "external_primaries" tag to allow the use of non-supported measurement instruments. Used as a flag, this attribute supports values of "TRUE" and "FALSE". It should be set to "FALSE" unless an `external_primaries` tag is also included in the StudioCal XML file. Use of this tag is discussed on page 13.

Gamma

This tag allows you to specify the gamma curve that will be calculated for your color space preset. The tag contains one attribute and is structured as follows:

```
<gamma value="FLOAT|sRGB|BT1886"/>
```

The `value` attribute supports the following values:

- **1.0–3.0**: Numerical gamma values. Typical values are 2.2, 2.4, and 2.6.
- **sRGB**: Generates an sRGB curve per the sRGB standard. This gamma curve is roughly equivalent to a 2.4 gamma with a linear segment in the lower region.
- **BT1886**: Generates a gamma curve as specified in ITU-R BT.1886. This gamma is designed to more closely represent the desired response for video production and is typically used with the BT.709 color primaries.

Core Calibration Tag Example

The following is an example of an XML file showing the usage of the core calibration tags. This XML file will instruct the Z27x to calibrate to the BT.709 primaries, a D65 white point, and use the BT.1886 gamma curve. It will store the calibration in the factory memory location.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!--BT.709/BT.1886 calibration-->
<studiocal>
    <preset num="3" name="BT.709" store="factory"/>
    <gamma value="bt1886"/>
    <target_primaries rx="0.640" ry="0.330" gx="0.300" gy="0.600" bx="0.150"
    by="0.060" wx="0.3127" wy="0.329" wY="80" external="FALSE"/>
</studiocal>
```

Optional Calibration Tags

The following optional tags are designed to be added to the core calibration tags to provide additional capabilities.

Measurement Averaging

This tag allows you to make and average multiple measurements. If you are using a colorimeter for calibration measurements you may want to make multiple measurements of lower grayscale levels to compensate for the noise inherent in some colorimeters. (As spectroradiometers have less low grayscale noise, this option is not typically used when measuring with those instruments.)

The tag contains two attributes and is structured as follows:

```
<average_meas N="INTEGER" use_below_RGB="INTEGER"/>
```

- **N**: The number of measurements to be taken and averaged. Integer values between 2 and 10 are supported.
- **use_below_RGB**: the RGB grayscale value below which you wish to make and average multiple measurements. A single 8-bit value between 1 and 255 is supported.

Set Linear Segment

This tag allows you to specify a grayscale value at which the gamma will switch from the calculated curve to a pure linear transition to zero. This is designed to allow you to mimic the measured performance of some projectors.

The tag contains one attribute and is structured as follows:

```
<set_linear_segment value="INTEGER"/>
```

The `value` attribute supports 8-bit values between 1 and 255.

Select Klein Cal File

This tag is specific to the Klein K10-A and allows you to specify any cal file stored in the instrument as the matrix used for measurements. The default cal file for Z27x calibration is 14 and that is the one calibrated at Klein Instruments, but you may desire to generate your own matrix using ChromaSurf.

This tag contains one attribute and is structured as follows:

```
<klein_cal value="INTEGER"/>
```

The `value` attribute supports integer values from 0–89.

Validation

After calibration, the display can be instructed to measure a set of patterns and record the measurements into a text file on the flash drive containing the studiocal.xml file. There are three tags associated with validation:

Validation On/Off

This tag allows you to specify whether validation will be performed post-calibration. It is an optional tag and is only required if you want validation to be enabled. It supports an off state so that you can quickly switch the attribute without removing all validation tags from the StudioCal XML file.

The tag contains one attribute and is structured as follows:

```
<validate_flag value="TRUE|FALSE"/>
```

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If `value` is set to false all other validation tags in the XML flag are ignored. However, two different behaviors can occur if `value` is set to true:

- If the other validation tags are present, the display will read those tags to determine the patterns to be measured.
- If the other validation tags are not present, then the X-Rite ColorChecker patterns are displayed and measured.

Validation Pattern Parent Element
This parent element holds the child elements that will provide the RGB triplets of the patterns to be displayed. It also contains an attribute which allows you to specify the number of patterns that will be measured. Note that as a parent element a closing tag must be used after the list of child elements.

The tag contains one attribute and is structured as follows:

```
<validation_pattern entries="INTEGER"/>
```

The entries attribute supports values between 1 and 10.

Validation Pattern Child Element
The child element defines the RGB values that will be displayed for each pattern. It contains three elements and is structured as follows:

```
<valid_rgb r="INTEGER" g="INTEGER" b="INTEGER"/>
```

All three attributes accept 8-bit values from 0 to 255.

Validation Code Example
The following is the XML file shown earlier, this time with the validation tags added. It will display the 100% white, black, red, green, and blue.

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<!--BT.709/BT.1886 calibration with validation-->
<studiocal>
     <validate_flag value="TRUE"/>
     <preset num="3" name="BT.709" store="factory"/>
     <gamma value="bt1886"/>
     <target_primaries rx="0.640" ry="0.330" gx="0.300" gy="0.600" bx="0.150"
     by="0.060" wx="0.3127" wy="0.329" wY="80" external="FALSE"/>
     <validation_pattern entries="8">
            <valid_rgb r="255" g="255" b="255"/>
            <valid_rgb r="0" g="0" b="0"/>
            <valid_rgb r="255" g="0" b="0"/>
            <valid_rgb r="0" g="255" b="0"/>
            <valid_rgb r="0" g="0" b="255"/>
            <valid_rgb r="0" g="255" b="255"/>
            <valid_rgb r="255" g="0" b="255"/>
            <valid_rgb r="255" g="255" b="0"/>
     </validation_pattern>
</studiocal>
```

Validation Results File
When validation is enabled, a text file is created containing all measurements made during calibration. The filename includes the display serial number and a unique three digit number. The file is broken into multiple parts, with header lines, prefixed with #, for each section. Unless otherwise noted, if the section contains measurements the RGB triplets (in 8-bit RGB) and the measurement data (in CIE XYZ) for each pattern is listed.

The following file sections are included:

- **#Calibration Equipment**: Lists the measurement instrument used for the calibration.
- **#MEAS_NUM**: The number of measurements made when characterizing the display.
- **#MEAS_DATA**: The measurements taken to characterize the display.
- **#PRESET NAME**: The name assigned to the preset.
- **#VALID RGB** or **#Color Checker**: Defines whether user-supplied patterns or X-Rite Color Checker patterns were used for validation. Following this header are the RGB triplet and post-calibration measurement data for each pattern.
- **#Primary Colors**: Post-calibration measurements of 100% saturation primaries.

- **#Secondary Colors**: Post-calibration measurements of 100% saturation secondaries.
- **#Target Primaries**: The CIE xy values for the desired primaries and white point, and the white point luminance in cd/m².
- **#Calibrated Primaries**: The CIE xy measurements for calibrated primaries and white point, and the white point luminance in cd/m².
- **#Calibrated Secondaries**: The CIE xy measurements for the calibrated secondaries.

LUT Archiving, Downloading and Uploading

StudioCal XML provides three different tags that allow you to save the PreLUT, matrix, and PostLUT to a USB drive or to upload to the display from a USB drive.

Archive LUT

Designed to be used in conjunction with a calibration, the archive LUT tag instructs the display to download the calibrated LUTs and matrix to the USB flash drive containing the studiocal.xml file. The files are stored in a folder and the folder name is assigned as the calibrated preset's name.

The tag contains one attribute and is structured as follows:

```
<archive_lut_flag value="TRUE|FALSE"/>
```

If `value` is set to TRUE, at the end of the calibration the LUTs and matrix will be downloaded to the flash drive. If set to false, the tag is ignored.

Download LUT

Designed to be used independent of a calibration, the download LUT tag instructs the display to download the calibrated LUTs and matrix to the USB drive containing the studiocal.xml file.

The tag contains two attributes and is structured as follows:

```
<download_lut num="INTEGER" folder="ALPHA"/>
```

- **num**: the preset number you wish to download. Integer values from 0 to 6 are supported.
- **folder**: the name of the folder on the USB flash drive where you wish to store the LUT and matrix files. If the folder does not exist on the drive, it will be created.

Upload LUT

Designed to be used independent of a calibration, the upload LUT tag instructs the display to load LUT files stored on the attached USB drive and install them into the specified color space preset.

The tag contains four attributes and is structured as follows:

```
<upload_lut num="INTEGER" name="ALPHA" folder="ALPHA" store="user|factory"/>
```

- **num**: the preset number you wish to upload to. Integer values from 0 to 6 are supported.
- **name**: the name you wish to assign to the preset being created. Names can be up to fifteen characters in length and may consist of alphanumeric (A–Za–z0–9) characters, a period (.) and a space. All other ASCII characters are converted to periods.
- **folder**: the name of the folder on the USB flash drive where the LUT and matrix files are stored.
- **store**: Specifies the memory store that will be used and accepts the values "user" or "factory". The Z27x contains two different memory stores: factory and user.
  - The factory store is a protected memory location and is where the factory calibration is stored. When a calibration is written to the factory memory location, the user memory location is also rewritten to match the factory memory location. This location can only be rewritten via StudioCal.XML and this option is provided to allow facilities and studios to store a calibration that can easily be recalled via the "Reset to Factory Calibration" or "Factory Reset" command.
  - The user store is the memory location where all menu-driven calibrations are stored. This memory location is not protected and will be rewritten when any type of calibration is performed or if a "Factory Calibration" or Factory Reset" command is issued.

LUT Folder Structure

A LUT folder must contain four text files. Each file has a name that identifies preset name, preset number, and type of information stored within the file, or "name-num-type." For example, if the preset name was "BT.709" and the preset number was "2", then each LUT file name would have the prefix "BT.709-2." The following files are required in a LUT folder:

- **name-num-PreLUT.txt**: an ASCII text file which conforms to the 1D ASCII format. The first line of the LUT file is the declaration and indicates the number of LUTs in the file (usually 3, one each for red, green, and blue), the number of entries in each lut, and the bit precision of the LUT values. For example, LUTs downloaded from the Z27x have the following declaration:

```
LUT: 3 1024 14-bit
```

Optional comments may be used to store the color space preset the LUT was generated for, the type of LUT (PreLUT or PostLUT) and the beginning of each channel LUT. The Z27x automatically generates all of these comments to make the LUT file more human-readable. The following is an example of a LUT file:

```
LUT: 3 1024 14-bit
# BT.709 #
# PreLUT #
# Begin Red #
0
1
…
16344
16383
#Begin Green #
0
1
…
16344
16383
#Begin Blue #
0
1
…
16344
16383
# END #
```

- **name-num-3x3.txt**: an ASCII text file which contains the 3×3 matrix data. The first line of the LUT file is a declaration indicating it is a 3×3 matrix. The second line is an optional comment indicating the name of the color space preset the 3×3 matrix was generated for. Then follows three lines of three numbers representing the matrix. The entries on each line are tab delimited. The final line is an optional end comment. The following is an example of a 3×3 matrix file:

```
# Lumen 3x3 Matrix
# BT.709 #
710   43     9
314   900    30
-1    10     963
# End #
```

- **name-num-PostLUT.txt**: an ASCII text file which conforms to the 1D ASCII format. See the name-num-PreLUT.txt entry above for information on the structure of this file.

- **name-num-PresetValue.xml:** an XML file that contains the information that is to be displayed in the Color Space Information on-screen menu and passed to the host computer via the EDID. This file is based on the Studio Cal XML schema, but uses the `<preset_values>` root element. A sample preset value file is shown below:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<preset_values>
    <gamma value= "2.4" />
    <target_primaries rx="0.640" ry="0.330" gx="0.300" gy = "0.600" bx="0.150"
    by="0.060" wx="0.313" wy="0.329" wY="100"/>
</preset_values>
```

Using Non-Supported Measurement Equipment

Though multiple measurement instruments are natively supported by the Z27x display, you may wish to use another instrument to make adjustments to an existing preset or to create another preset. Studio Cal XML supports this option via the `external_primaries` tag. Designed to operate similarly to the recalibration tool built into most Digital Cinema projectors, measurements are made of the *native* red, green, and blue primaries, and 100% white. This data is then provided to the calibration software via this tag.

There are two caveats to be aware of:

• As only primary and white point measurements are made with the external instrument, a new luminance target cannot be iterated. Therefore, the existing luminance value for the preset you are recalibrating will be used.

• Existing calibration measurement data *must* be present on the display in order for gamma to be correctly calculated. In most cases, factory data or data from your most-recent calibration with a supported instrument will be sufficient. If you have updated to the Z7X240 firmware any calibration data from a calibration – including factory calibration – performed on a previous firmware revision is no longer present.

This is an unavoidable side effect of the upgrade to Z7X240 as this update changes the entire memory partitioning for the display's internal processor. If this is the case on your display, you must do a calibration with a supported instrument prior to using this function. (This is not the case of new displays that shipped with Z7X240 as the firmware was installed prior to factory calibration.) Z7X230 and Z7X240 are functionally identical, with the exception of this memory partition change. Therefore it is not necessary to update to Z7X240 at this time. (It will, however, be required to update to future firmware updates when they are released.)

The `external_primaries` tag must be used in conjunction with the `target_primaries` tag. It contains eight attributes and is structured as follows:

```
<external_primaries rx="0.675" ry="0.315" gx="0.210" gy="0.705" bx="0.147"
by="0.054" wx="0.3129" wy="0.329"/>
```

The attributes are identical to those in target_primaries. See page 8 for more information on these attributes. As with `target_primaries`, the `use_uv` tag is optional.

Making Measurements With Non-Supported Measurement Equipment

As mentioned above, you must make measurements of the panel native primaries and white point so you should switch your display to the Native color space preset. This is the last preset on the on-screen menu preset list. To facilitate primary and white point measurements, it is recommended that you use the internal test pattern generator. (External generators can be used, if desired.) The internal test patterns are not accessible by default, but one of the four bezel button function keys can be set to display the pattern generator.

To set a function key to the test pattern generator:

1. Press any bezel button to display the initial button labels, then choose **Open Menu** to display the Main Menu.
2. Use the bezel button arrow keys to navigate to **Menu and Message Control** then press **Select**.
3. Navigate to **Configure Function Buttons** then press **Select**.
4. Navigate to the desired function button then press **Select** to display the list of commands that can be mapped.
5. Navigate to **Test Pattern Generator** then press **Select** to assign it to the function button.
6. Press **Exit** to close the on-screen menus.

Now that you have mapped the test patterns to a bezel button, you can use that function to display the required patterns. First, confirm that the display is set to the Native color space preset. Then, display the red, green, blue and white test patterns, and measure them with your instrument. Record the xy or u'v' measurements into an `external_primaries` tag in your Studio Cal XML file. Then enter the desired primaries and white point into a `target_primaries` tag in the same file.

The following is an example of an external measurements Studio Cal XML file:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<studiocal>
      <validate_flag value="FALSE"/>
      <archive_lut_flag value="FALSE"/>
      <preset num="0" name="sRGB Illum A" store="user"/>
      <gamma value="2.4"/>
      <target_primaries rx="0.640" ry="0.330" gx="0.300" gy="0.600" bx="0.150"
      by="0.060" wx="0.4476" wy="0.4074" wY="150" external="TRUE"/>
      <external_primaries rx="0.675" ry="0.315" gx="0.210" gy="0.705" bx="0.147"
      by="0.054" wx="0.3129" wy="0.329"/>
</studiocal>
```

When a USB drive is inserted into one of the two DreamColor USB ports the display will read the StudioCal file. You can generate a new color space based on the external measurements. Once generated the new color space preset will be generated and the display will switch to that preset. Then, with that color space active, you can use the test pattern generator to measure and verify the generated primaries.

Contrast Ratio Limiting

In some workflows – on-screen newsprint, for example – it is desirable to have a contrast ratio lower than the display's native contrast ratio. The Z27x provides two different tags for this workflow. The two tags each have two arguments and are structured as follows:

```
<cr_set_lumlow+cr lumlow="FLOAT" cr="INTEGER">
```

```
<cr_set_lumlow+lumhigh lumlow="FLOAT" lumhigh="FLOAT">
```

- **lumlow**: specifies the luminance value for 0% black
- **lumhigh**: specifies the luminance value for 100% white
- **cr**: specifies the desired contrast ratio

Use the tag that best-matches your workflow. In each case, the LUTs will be calculated so that a lower contrast is achieved than would normally be the case.

Display Settings Uploading and Downloading

Though Studio Cal XML is designed for calibration-type functions, it is designed to be extended to support additional functionality in future firmware releases. New to the Z7X230 firmware release is a tag that allows you to export a Z27x display configuration to an XML file and then load that configuration back to the same display or deploy it to other displays.

This tag was designed to facilitate the "configure, calibrate, and deploy" model used by many large VFX and animation studios. With this tag, IT can configure a single Z27x display so that all menus are configured as desired then deploy that configuration onto all other Z27x displays in the facility. As this command is not calibration-focused it cannot be used with calibration-specific tags.

The tag contains two attributes and is structured as follows:

```
<user_settings operation="save|load"/>
```

The operation tag can be set to either "save" or "load." If set to "save" the display's configuration will be written to a file named "Z27X_UserSettings.xml" on the root of the attached USB drive. (If this file already exists on the drive it will be overwritten. Though this file is human-readable it is not designed to be manually edited and as a result the tag attributes are not documented. If an attribute has been changed to a value that is out of range that attribute will be skipped when being loaded into the display.

If set to "load" the "Z27X_UserSettings.xml" file must be present on the inserted USB drive. It will then load the settings into the display, replacing all existing settings with the new settings. Color space presets, being calibration-based, are not affected by this command.

Resources, contacts, or additional links
HP DreamColor Z27x Firmware Updates and additional software
http://h20565.www2.hp.com/portal/site/hpsc/public/psi/swdHome/?lang=en&cc=us&sp4ts.oid=6644017

Learn more at
hp.com/DreamColor

Sign up for updates
hp.com/go/getupdated

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